

# **Radar Measurement of Waves and Currents in the Nearshore Zone During NCEX**

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## **LONG-TERM GOALS**

My long-term goal is to contribute to our understanding of the upper ocean and lower atmosphere through the development and application of novel microwave, acoustic, and optical remote sensing techniques.

## **OBJECTIVES**

The objectives of this effort are (1) to establish whether Doppler radar techniques can provide useful estimates of nearshore currents within and beyond the surf zone and (2) to develop and apply Doppler radar techniques to large area surface wave and current mapping in the nearshore environment.

## **APPROACH**

Our approach has been to observe the nearshore with two microwave marine radars modified for ocean remote sensing. These systems were deployed at the Nearshore Canyon Experiment (NCEX) in 2003 to provide synoptic images of the incident wave fields and surface currents, through measurement of backscattered power and Doppler velocities. We use sequences of backscattered power images, and techniques similar to that of particle image velocimetry (PIV) to estimate surface current vectors in the nearshore. We plan to use our Doppler velocity measurements to develop retrieval techniques for surf zone flows. We are in the process of comparing our surface velocity measurements with in situ surface velocities, and where possible, with surface velocity measurements made by other remote sensing techniques.

## **WORK COMPLETED**

In October and November of 2003, we deployed two modified Rathyeon Pathfinder marine navigation radars along the coast of southern California, during the Nearshore Canyon Experiment (NCEX). The antennas on these radars had been changed to vertical polarization, and the receivers modified to record the Doppler shift in backscattered energy. One radar was deployed approximately 70 m above MSL on top of the Southwest Fisheries Science Center (SWFSC) in La Jolla, and the other in the UCSD parking lot at the Torrey Pines City Beach (more commonly known as Black's Beach), approximately 25 m above MSL overlooking the southern portion of beach and nearshore. The SWFSC radar (designed WMR1), ran for 24 hours a day, whereas the Black's Beach radar (WMR2), was limited to around 10 hours of

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operation a day due to the cost of the generator.

We have completed georeferencing the radar data to Oregon State University’s Scripps Argus Camera coordinate system used by their Argus coastal monitoring video cameras, and by other researchers at NCEX. Georeferenced radar data allows us to compare with other instrumentation and to relate our surface measurements to the local bathymetry.

We have implemented a feature tracking algorithm to extract surface movements seaward of the surf zone observed in our radar images. This algorithm is similar to video based PIV techniques used within the surf zone to measure surf zone flows. The results of this algorithm are presented in the next section of this report. We are currently collaborating with S. Elgar, B. Raubenheimer (WHOI), and R. Guza (SIO) to compare radar-image-derived surface velocities with subsurface current meter measurements. Todd Holland (NRL) has also provided video images from NCEX which are helping us interpret the source of scattering in the radar measurements. Several other collaborations with NCEX investigators are planned on various aspects of the radar observations.

## RESULTS

During NCEX, under conditions of low wind, we observed patches of increased radar backscatter that appear to be collocated with patches of foam in the nearshore. Such low grazing angle scattering from foam has not been published in the literature to our knowledge. An example of a typical radar image of backscattered power recorded during these conditions is shown in Figure 1. The image is constructed from a time average of 40 consecutive scans or 56 seconds; low signal to noise ratio samples have been set to a background color of dark blue to distinguish areas of no signal. Three distinct regions in the image are evident. In the lower left hand corner, bright white features ( $< 130$  dB) are cliffs and land-based features. Along the coast, a band of backscatter characterized by values of around 125 dB to 130 dB is the surf zone. In this region, breaking waves account for the majority of the backscatter. Outside the surf zone, for large portions of the area, backscatter is below the sensitivity of the radar; however, distinct patches of backscatter can be seen. Animation of a sequence of such images show mean longshore movement of these patches, and rip current like structures emanating from the surf zone.

Figure 2 shows velocity vectors produced with our feature tracking algorithm, using data shown in Figure 1. Vector nodes are spaced in a  $20 \times 20$  meter grid. Two flows with an offshore directed component are evident in the velocity field at around  $(300, -600)$  and  $(300, -1100)$ . These merge with a southward directed longshore flow that occurs predominantly shoreward the  $-10$  meter contour line. Offshore from this, to the south, there appears to be a northward directed longshore flow, and a resulting circulation where these oppositely directed flows meet. Examples of questionable vectors not removed by our detection algorithm can be seen at locations  $(550, -450)$  and  $(510, -1150)$ . However, the large scale structure of the features observed in the velocity field are similar to flows one may expect to find in the nearshore region.

Measurements from seven in situ current meters were available over the region measured by the radar. Figure 3 shows 5 minute time averages of subsurface current vectors (blue) measured by the in situ current meters, and surface velocity vectors (black) derived from the radar data during the period 04h15 to 04h20 UTC on October 25. The vectors are not exactly collocated because of the finite node spacing in the radar processing. In both cases, longshore and cross shore components were time averaged over

a 5 minute period to remove any wave induced motion measured by the current meters. These results are encouraging since they indicate that the feature tracking algorithm is producing estimates of surface flows.

## **IMPACT/APPLICATIONS**

The significance of the research lies in the ability to interpret radar measurements of the nearshore to provide synoptic measurement of nearshore processes. The high resolution vector map of surface velocities presented in this report is unique in the spatial coverage provided over the nearshore region. If successfully validated through comparison with other techniques, this data product should prove extremely useful in the study of the three dimensional structure of nearshore flows. Furthermore, these measurements have allowed us to develop new techniques for observing nearshore dynamics with microwave radar under low wind conditions.

## **TRANSITIONS**

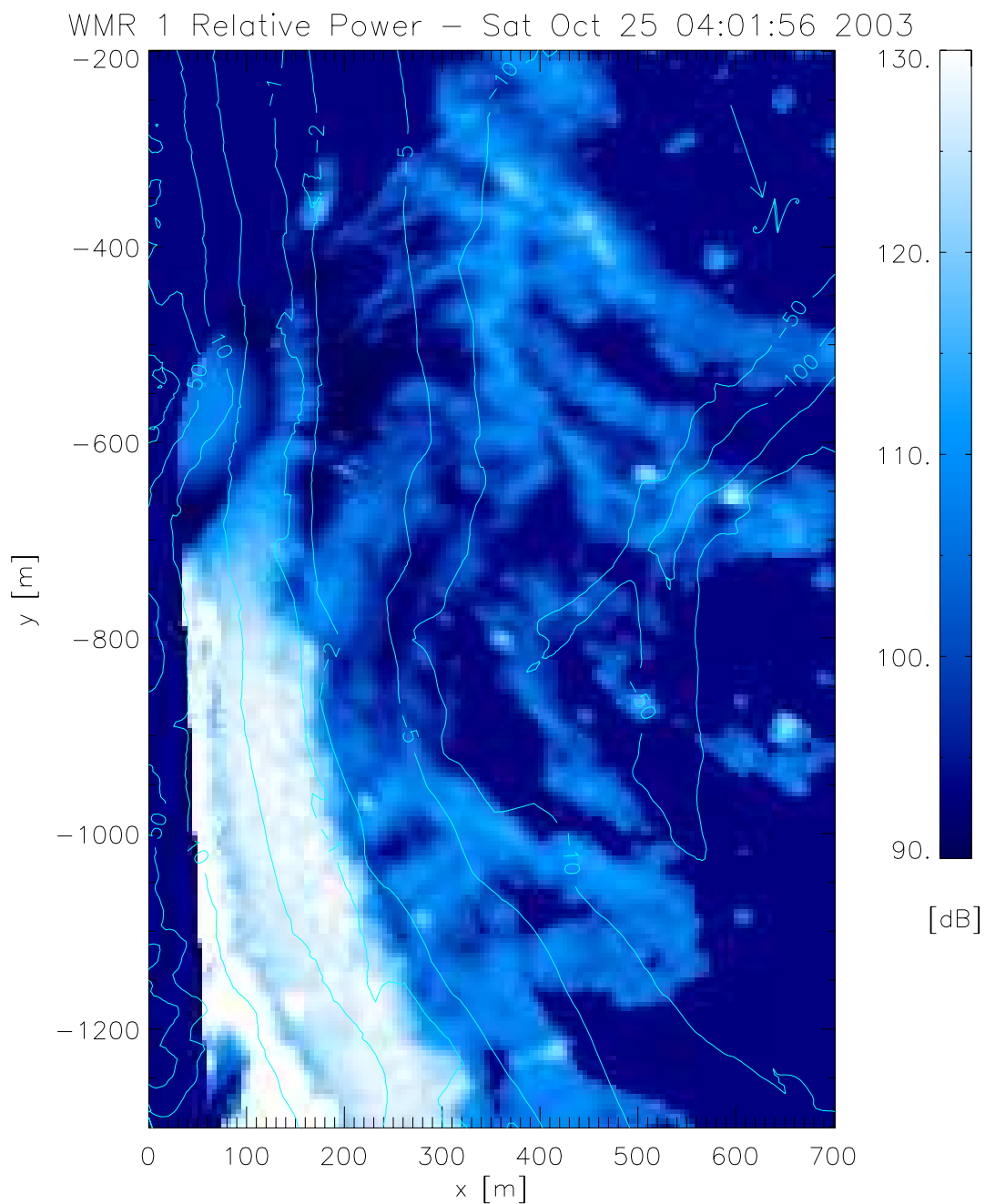
None

## **RELATED PROJECTS**

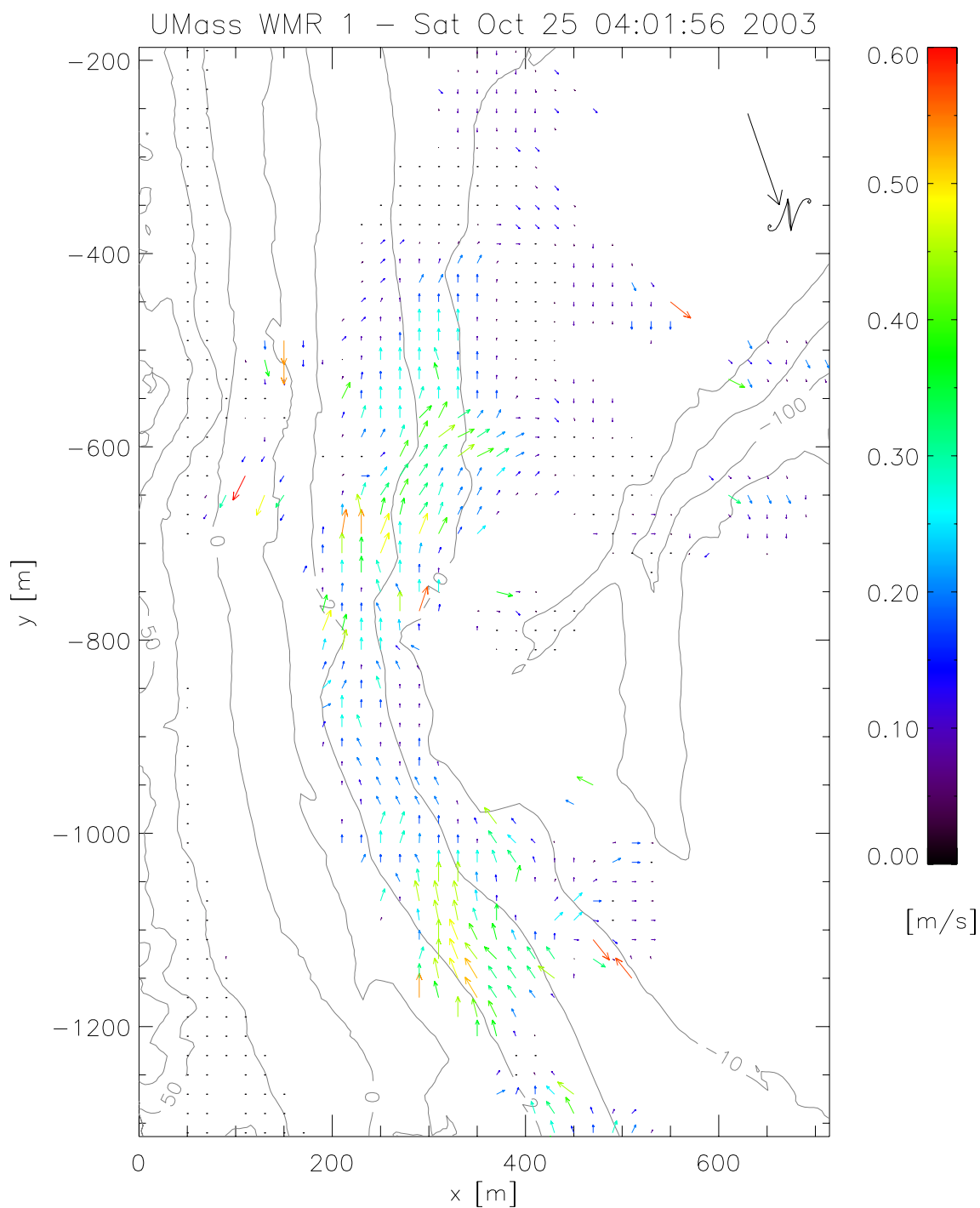
The interpretation of Doppler velocities from the ocean is similar to that required by our airborne interferometric SAR, the Dual-Beam Interferometer (DBI). Under separate ONR support, and through a collaboration with the Naval Research Laboratory, we have made measurements of surface currents along the east coast of Florida, and over the Gulf Stream, west of Florida.

## **PUBLICATIONS**

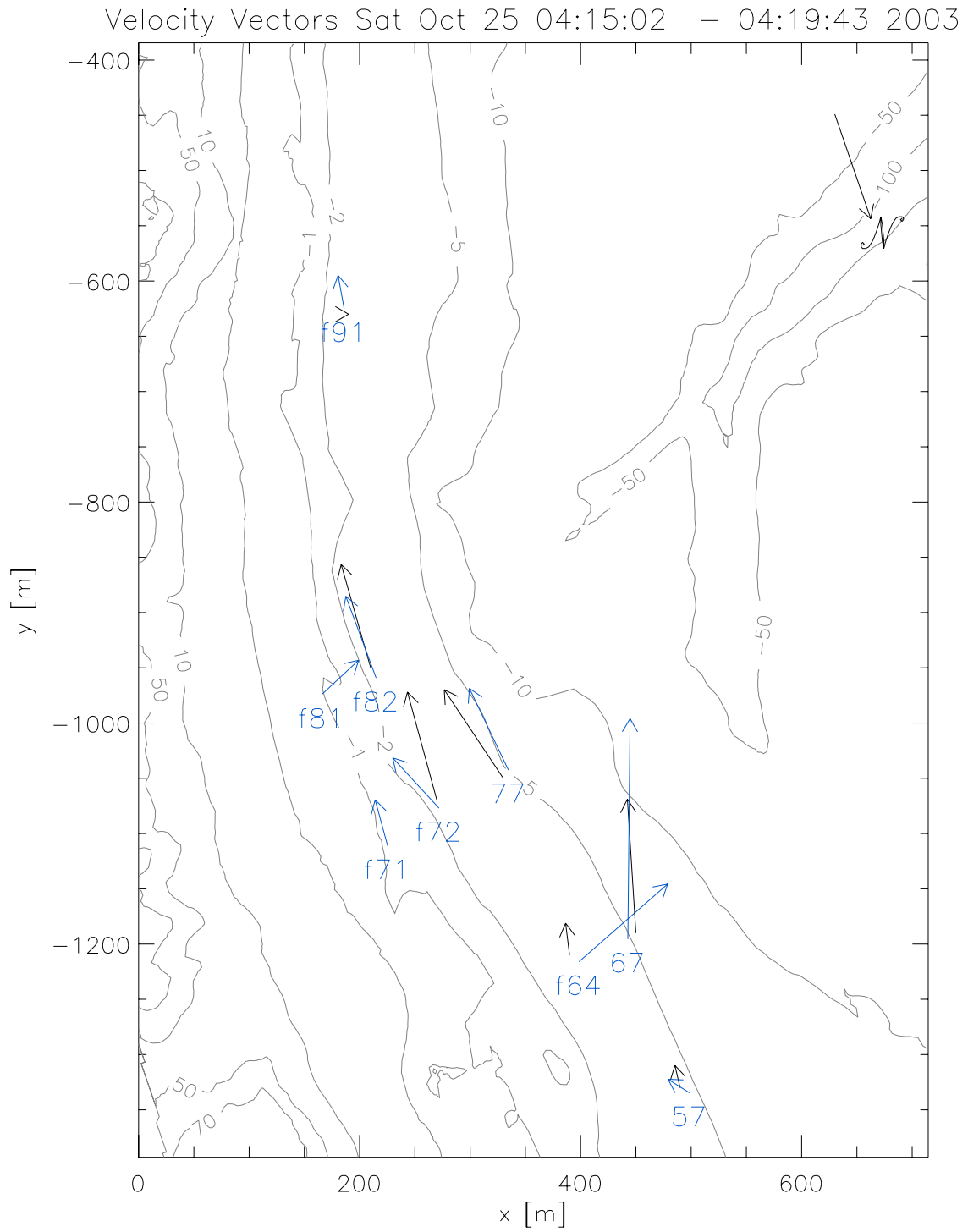
Puleo, J.A., G. Farquharson, S.J. Fraiser, and K.T. Holland, 2003. "Comparison of optical and radar measurements of surf and swash zone velocity fields", *J. Geophys. Res.*, **108**(C3), 3100, doi:10.1029/2002JC001483.



***Figure 1: Radar image from South West Fisheries Science Center under low wind and wave conditions. Patches of increased backscattered power are evident in the nearshore. Topographic contour lines show the coast and also the Scripps sub-marine canyon.***



**Figure 2: Surface movement velocity vectors extracted from radar backscattered power images of the nearshore. Surface velocities range from a few centimeters per second to around 60 cm/s. Vectors within the surf zone have been removed.**



**Figure 3: Comparison of 5 minute averaged surface (radar, black) and subsurface (in situ, blue) velocity vectors in the nearshore. Radar measurements were excluded for sensor locations £71 and £81 due to the presence of the surf zone.**